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RECENT DEVELOPMENTS IN EDUCATIONAL RESEARCH METHODOLOGY.

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298 EDUCATIONAL AND PSYCHOLOGICAL RESEARCH PAPERS PUBLISHED IN 5 JOURNALS DURING 1966-67 WERE CLASSIFIED ON THE BASIS OF SPONSORSHIP, AUTHORS' GENERAL INTENTIONS, DESIGN, ASSUMPTIONS, AND ANALYSIS. ADVANCES IN STATISTICAL THEORY (INCLUDING WORK ON GENERAL ANALYSIS OF VARIANCE DESIGNS, HYPOTHESIS TESTING IN FACTOR ANALYSIS, MULTIVARIATE ANALYSIS, FACTOR ANALYSIS, AND NON-METRIC DATA ANALYSIS) ARE DISCUSSED. BECAUSE OF THE RECENT PROLIFERATION OF STATISTICAL METHODOLOGY, RESEARCH IS SUGGESTED ON WHETHER DIFFERENT METHODS LEAD TO SUBSTANTIALLY DIFFERENT INTERPRETATIONS OF DATA, AND WHETHER ALGORITHMS ARE COMPUTED DIFFERENTLY WHEN MACHINES AND PROGRAMS OF DIFFERENT DESIGNS ARE EMPLOYED. IN GENERAL, INCREASED USE OF MULTIVARIATE METHODS IS RECOMMENDED. PAPER READ AT 1967 RESEARCH CONVOCATION OF THE EDUC. RES. ASSOC. OF N.Y. STATE (ALBANY, NOV. 1967). (AF)

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Recent Developemnts in Educational Research Methodology*

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Perhaps it is by now a truism that the most significant advances in any science are presaged by inventions of new machinery or methods for conducting research. Thus, surely to a great extent, advances in education and psychology are dependent upon advances in research methodology. We have two related purposes in this short session. First, we wish to document the status of research methods which are typically used today and second, to point to new developments in methodological theory which appear likely to advance the practices of educational and psychological researchers in the future.

The first part of this paper is devoted to a summary of the results of a survey of recently-published research in the educational and psychological literature. In the second part we shall describe briefly certain new developments in research methodology which seem to us to have special potential. Our most important overall objective is to encourage the reader to learn more about these new developments which are described in the references listed at the end of this paper.

To begin, we surveyed 298 papers which were published during 1966 and 1967 in five Journals which are identified in Table 1.

Table 1. Journals Reviewed

Journal	Issues Covered	No. of Papers
American Educational Research Journal	Jan. 1966-May 1967	51*
Educational and Psychological Measurement	Spr. 1966-Sum. 1967	66
Journal of Educational Measurement	Spr. 1966-Sum. 1967	39
Journal of Educational Psychology	Feb. 1966-Aug. 1967	88*
Multivariate Behavioral Research	Jan. 1966-Jul. 1967	54

* Three papers from AERJ and two from JEP contained no explicit or implicit treatment of data.

All papers were classified on the basis of sponsorship, authors' general intentions, design, assumptions and analysis. Specifically, we classified each

paper with respect to each of the five dichotomies:*

1 A supported paper is one for which the cost of basic research was wholly or partially underwritten by an agency other than the one in which an author was regularly employed. All others are non-supported.

2 A methodological paper is one whose discussion and conclusions indicate a desire to disseminate a method of analysis or to comment on an extant one. A substantive paper's discussion and conclusions focus on the individuals or attributes studied.

3 An observational paper examines intact groups, applying the same tests and/or treatments to all individuals. A manipulative paper assigns different treatments.

4 A multivariate paper is one using some form of factor analysis, component analysis, discriminant function analysis, or multivariate analysis of variance. All others are univariate, including those using complex analysis of variance.

5 A metric paper is one that at least implicitly assumes underlying measurement on an interval or ratio scale. All others are non-metric.

Our concern here shall be with a review of salient features of the classification data which is presented in Table 2.

*The reader will recognize that not all papers can easily be categorized along all of these variables. While some arbitrariness is inevitable and a re-examination might show slightly different results we feel that the dichotomizations presented herein are at least internally consistent.

Table 2. Five-way Classification of 298 Papers in Education and Psychology

(Note: Frequencies are listed in 2 x 2 tables below the diagonal; phi-coefficients above.)

	SUP	NSP	SUB	MTH	MAN	OBS	UNI	MUL	NMT	MTR
Non-Supported (NSP) Supported (SUP)			.17		.13		-.05		.00	
Methodological (MTH) Substantive (SUB)	17 115	45 121			.23		.28		.14	
Observational (OBS) Manipulative (MAN)	83 49	124 42	151 85	56 6			.40		.16	
Multivariate (MUL) Univariate (UNI)	49 82	53 109	66 169	36 22	5 83	97 108			.04	
Metric (MTR) Non-Metric (NMT)	108 23	134 28	200 35	42 16	81 7	161 44	160 31	82 20		

Consider first the support--non-support dichotomy. From Table 2 we may see that granting agencies have come to be associated with a substantial proportion of published papers in this field. 44% of the papers surveyed were prepared with at least some financial assistance from outside the institution in which the investigators worked. From the phi coefficient in row 1 and column 2 (.17) we see that, for these journals at least, supported work, more than non-supported work, is likely to be of a substantive nature. It is interesting to note that there is so little correspondence between the support--non-support dimension and the multivariate dimension, despite the greater cost of data processing of multivariate data. Perhaps this means that nearly everyone who currently publishes has a computer at his disposal for data analysis.

Consider next the metric-non-metric dichotomy. From frequencies in Table 2, it may be seen that 83% of the papers surveyed at least tacitly assume interval or ratio scales for measurement. Clearly this is not the appropriate place to debate relative virtues of parametric versus non-parametric procedures for data analysis in education in psychology; the point is that most researchers have opted for parametric procedures in their analyses.

There are several interesting findings which relate to the multivariate--univariate classification variable. First, 35% of the papers examined involve some sort of multivariate procedure in either data analysis or discussion; this percentage drops to 22% when we exclude Multivariate Behavioral Research, but still it is clear that roughly one fourth of the papers currently reported cannot be fully understood unless the reader has some familiarity with multivariate methods.

While it is not apparent from data in Table 2, it was clear from our examination of the papers, that very few studies using multivariate methods were concerned with cognitive variables; most such papers in these journals were concerned with personality--or affective--variables. Of course, many multivariate studies in the past have been concerned with achievement and aptitude variables, but it would be unfortunate if we were not to continue to have multivariate studies of cognitive variables.

A finding which troubles us most and about which subsequent remarks will be particularly relevant is reflected by the high correlation (.40) in Table 2 between the univariate--multivariate dimension and the manipulative--observational dimension. When experimental methods, or treatment manipulations, are involved in a study one can be nearly certain that multivariate methods will not be employed in data analysis. See the frequencies in the associated four-fold table below the principal diagonal. Thus, it may be fairly stated that very little research of a scientific inferential nature is being conducted using multi-

variate methods for analysis. Given that in education and psychology most of our manipulative studies are concerned with more than one dependent variable, this seems to be particularly unfortunate.

We hope that you will find the entries in Table 2 worth further study but for now we move on to consider certain advances in methodological theory.

Given our pessimism relating to the use of multivariate methods in research we now suggest some reasons for optimism. For persons who are likely to be gathering and analyzing multivariate data in the future we think that recent work on general analysis of variance designs by Bock and Bargmann and work on hypothesis testing in factor analysis by Joreskog are especially worthy of attention.

Bock and Bargmann published a quite readable paper (#2) on analysis of convariance structures in which they describe methods for estimating variance components in the following general situation: Suppose one has gathered responses on a sample of persons for a number of variables (such as tests, or test items) in which the variables can be placed in a fixed set of categories using a factorial or a hierarchical design. For example, classification variables might be item format characteristics, content characteristics, features of the administration of the tests, etc. If an investigator wishes to discover which classification variables or combinations of them are useful in discriminating among respondants, as well as the relative "importance" of these dimensions for distinguishing respondants, he may get this information directly from estimates of variance components. The methods of Bock and Bargmann are scale-free in the sense that units of measurement may differ across variables without influencing the results. While many applications of these methods can be imagined, we should be most interested to see studies in which achievement tests were arranged

in a design with respect to various content characteristics, format characteristics, difficulty levels, etc., to learn more about the relative importance of such classifications in discriminating among students. Different types of students might also be studied.

Karl Joreskog's work constitutes a large break-through in statistical methods for factor analysis. In a paper published in 1966 and another presented in 1967 Joreskog indicated his solutions to theoretical and computational problems associated with hypothesis testing in maximum likelihood factor analysis. When an investigator has hypothesized (or fixed) values for any number of entries in a population factor pattern matrix, a factor intercorrelation matrix, or a matrix of uniqueness variances, Joreskog has now shown how it is possible to generate precise confidence intervals for each free (or unfixed) parameter. The method is scale free and very unrestrictive as to possible applications. Results reported in (9) show that the widths of confidence intervals do not vary systematically with the size of the factor coefficients, or factor intercorrelations, but that they do vary substantially from one entry to another.

Perhaps some persons will be surprised to learn that by bridging the gap between Joreskog's work and that of Bock and Bargmann it is possible to show substantial similarities between general mixed models in analysis of variance designs and statistical inferential factor analysis models. The major difference lies in the degree and type of specification required for design parameters. Perhaps we are finally on the way to breaking down the experimentalist--correlationalist dichotomy which has so long been perceived as necessary by behavioral scientists.

We refer you to two reviews in the December 1966 Review of Educational Research to document further, recent work in multivariate analysis including multivariate analysis of variance and to point out numerous important advances in factor analysis methodology. Glass and Taylor (5) presented a paper which

was particularly readable and enlightened as to the significance of recent developments in factor analysis and Cramer and Bock (4) described recent developments in multivariate analysis, including multivariate analysis of variance.

Other developments in research methodology which are generally not yet available in the literature are concerned with non-metric data analysis. For reasons which are probably obvious to most behavioral scientists, many investigators have begun to emphasize approaches to data analysis which make very weak assumptions about underlying metrics. Coombs, in his 1964 book, A Theory of Data, was one of the first persons to make contributions in this area, but now we have recent work especially by Guttman (6) which shows more clearly the relevance of such approaches to conventional problems. These approaches emphasize identification of configurations or patterns in data as opposed to more common searches for underlying coordinate systems; computer programs have been worked and these developments will no doubt see important applications soon.

A new model related to Guttman's work is that of Wiley (11) on latent partition analysis. This model is appropriate for use when one has obtained several categorizations of a set of objects or items and wishes to study relationships among the categorizations. For example, if one has obtained several mutually exclusive and exhaustive qualitative categorizations of test items with respect to some general sorting criterion, he may use this model to see whether the hypothesis of underlying latent categories is tenable. Empirical work with this model has lead several of us to be optimistic about further applications.

Let us close by suggesting some new directions for research, the need for which is a direct consequence of the proliferation of methodology. Surely it is becoming clear that for some types of data at least, there are several distinct

and theoretically compelling methods which are available for analysis. But little is known generally about whether different methods will lead to substantially different interpretations of data. Some very limited studies have already been designed to study "method variance" in relation to, say, "content variance" but it would be good to see intensive systematic studies in this direction. In addition to being generally ignorant about such differences in methods, we are also quite ignorant about differences in computing algorithms when machines and programs of different designs are employed. Obviously there will be no end to methodological problems of this kind but if we are to get on to the important substantive problems of educational and psychological research we will need first to obtain answers to these questions about differences in methods.

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